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The Microstructure and Physical Properties of Incinerated Paper-Cullet-Clay Ceramics

M.R.Sahar[a*], K. Hamzah[a], M.S.Rohani[a], K.A.Samah[a], M.M.Razi[a],

[a]*Advanced Optical Material Research Group, Physics Department, Faculty of Science, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

Abstract

A series of ceramic based on (x) incinerated recycle paper - (80-x) cullet – 20 Kaolin clay (where $10 \leq x \leq 45$ wt%) has successfully been made by slip casting technique followed by sintering at 1000°C. The actual composition of ceramic is analyzed using Energy Dispersive of X-Ray (EDAX) while the phase existence is determined using X-Ray Diffraction (XRD) technique. Their microstructural morphology is observed under Scanning Electron Microscope (SEM) and the physical properties are measured in term of their thermal shrinkage and hardness. It is found that the ceramic contain mostly of Silica and the phase is dominated by the existence of Quartz (SiO2), Wollastonite (CaSiO3) and Anorthite (Ca(Al2SiO8)). The SEM micrograph shows that the morphology is dominated by the existence of granular structure, and then become smoother as the cullet level is further increased. It is also found out that the thermal shrinkage is in the range 18% - 6.5% while the hardness is in the range of 152MPa- 1.463GPa depending on composition.

Keywords: Incinerated paper; Glass Cullet; Hardness; Microstrtucture and Physical properties.

1. Introduction

The issues regarding to the disposal of the municipal solid wastes (MSW) had receive a lot of attention especially from the environmental point of view. Because of that, any activity that will enable its reduction and valorization is almost welcome [1]. According to report [2], cullet is a major contribution to

* Corresponding author. Tel.: +6-012-738-1709
E-mail address: mrahim057@gmail.com

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the municipal solid waste (MSW) collection. As has been demonstrated by other researchers [3-4], this cullet can be used as a fluxing agent in ceramic production such as stoneware, tiles, bricks concrete and cement. It can also reduce the sintering temperature when mixing with clay [5]. Consequently, cullet appears to be a suitable raw material for ceramic bodies since it contained of SiO_2, CaO, Na_2O and Al_2O_3 [6].

The mixture of cullet with incinerate paper waste is very promising since they are composed of refractory materials [6]. It has recently been demonstrated these mixtures, when added with red clay give products with properties that meet industrial standards [7]. Thus, it is clear that much work has to be done to promote increase the usage of cullet in different areas.

In the present study, the compositional, microstructure and crystal phases of the ceramic-based cullet- incinerated paper- Kaolin clay will be discussed in detailed. The thermal shrinkage and hardness of the sample also will be presented.

2. Materials and Methods:

A proportional amount of cullet, incinerated recycle paper and Kaolin clay of 100μm in size are mixed together according to the composition given in Table 1. The mixture is then homogenized using ball milling for 1 hrs before a 100 wt% of water is added as a binder to form slurry. Slurry is then slipped cast in a mould made of plaster of Paris followed by drying for 5 hrs at room temperature. Then it is heat treated at 100°C for 24 hrs before being sintered at 1000°C for 2 hrs to finally get the white ceramic sample.

The actual composition of the sample is determined using Energy dispersive analysis of X-ray (EDAX). The phase occurrence is determined by X-ray Diffractometer using Cu K α radiation. Meanwhile, the microstructural morphology is observed by using Scanning Electron Microscope (SEM). The thermal shrinkage of sample is obtained by measuring the diameter ratio of the pre-sintered to the after sintered sample. The hardness is determined using a Vickers test (DVK-2, Matsuzawa Precision Machine) with an indentation of 49N for 10s.

3. Results and Discussion:

Table 1: The nominal composition and actual compositon of Cullet- incinerated recycle paper-Kaolin based ceramic.

Sample no	Nominal Composition (wt%)			Actual composition (mol%)				
	Cullet	Incinerated paper	Kaolin clay	SiO_2	Al_2O_3	CaO	Na_2O	K_2O
S_1	35	45	20	59.8	16.3	19.9	3.2	0.8
S_2	40	40	20	68.3	7.3	19.5	3.7	1.2
S_3	45	35	20	67.0	2.2	29.3	1.0	0.5
S_4	50	30	20	74	2.2	21.7	1.6	0.5
S_5	55	25	20	79.0	4.3	11.8	3.7	1.2
S_6	60	20	20	80.5	4.4	9.0	5.0	1.1
S_7	65	15	20	81.0	4.0	8.9	5.0	1.1
S_8	70	10	20	81.7	4.1	9.2	4.1	0.9

Table 1 shows the actual composition of oxides as analyzed by EDAX. As shown in Table 1, the major elements are SiO_2 , Al_2O_3 and CaO while others such as Na_2O, K_2O are relatively very small. This result indicates that these ceramic contained of more silicates as the cullet contain is increased.

Figure 1 shows a typical XRD pattern of the samples. From the analysis it shows that the sample contained of Quartz (SiO_2), Wollastonite ($CaSiO_3$) and Anorthite ($Ca(Al_2SiO_8)$) and some weak peak for CaO and Al_2O_3. These phases generally occur mostly in cement, ceramics and glass-ceramic materials that is produced from incinerated waste and glass powder. [6,8]. The increments of the cullet content in the samples had marked reduction in the CaO peak and Al_2O_3 peak while the presence of amorphous phases can be seen through sample S8.

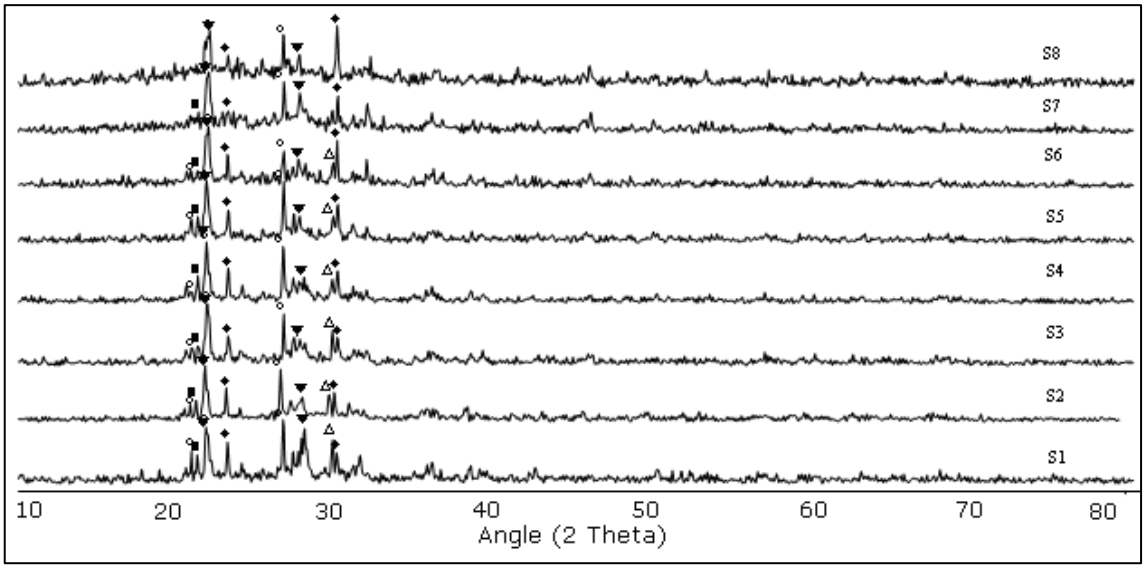
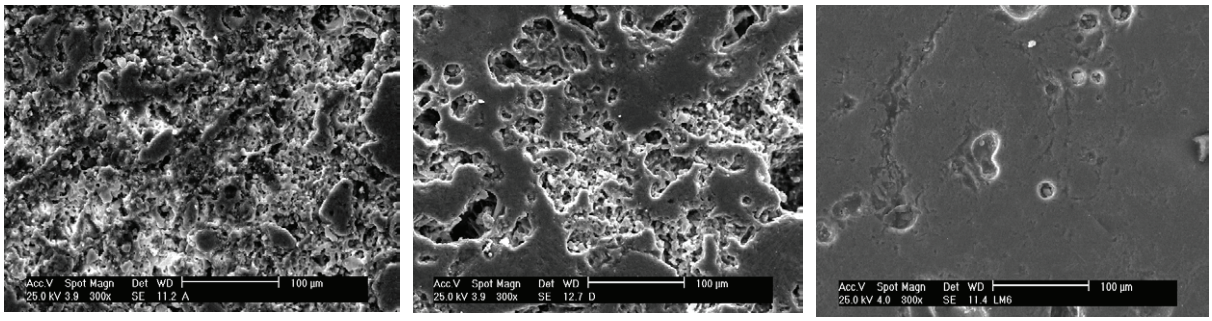


Figure 1. X-ray Diffraction patterns of the fired samples. Symbol used to identify the phases are as follows:
(○) = Quartz , (♦) = Wollastonite, (▼) = Anorthite, (■) = Al_2O_3, (Δ) = CaO

The surface morphology of samples containing 35wt% cullet (Figure 2(a)) exhibits the granular texture, rough, partial sintering and more pores due to the burning of organic matter that largely contained in incinerated recycle paper [9]. As the cullet level is increase to 50wt% (Fig. 2(b)), the surface contained a much smoother texture showing a higher degree of sintering and less pores. When the cullet level is increased up to 70wt% (Fig. 2(c)), the higher degree of vitreous phase with more smoothers texture can be observed. The increase in vitreous phase might be due to the transformation of SiO_2 and Al_2O_3 into liquid phase at higher temperature [10].



(a) (b) (c)

Figure 2. The surface morphology of a sintered sample at various cullet level as observed by SEM: (a) 35wt% cullet, (b) 50wt% cullet, (c)70wt% cullet.

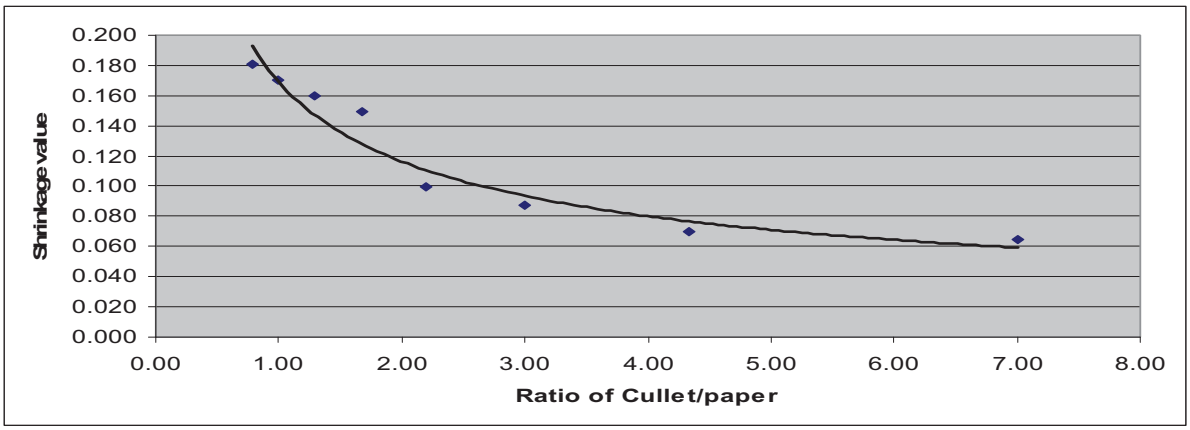


Figure 3. Shrinkage against the cullet/incinerated paper ratio

Figure 3 shows the correlation of thermal shrinkage against the ratio of cullet to incinerate recycle paper. From Figure 3, it can be seen that the shrinkage is reduce as the cullet level is increased. The decrement in thermal shrinkage might be attributed to the devitrification of cullet that would occur as the temperature is being increased. This process will cause all of the particles to move towards the centre thus reducing the size of the samples [11]

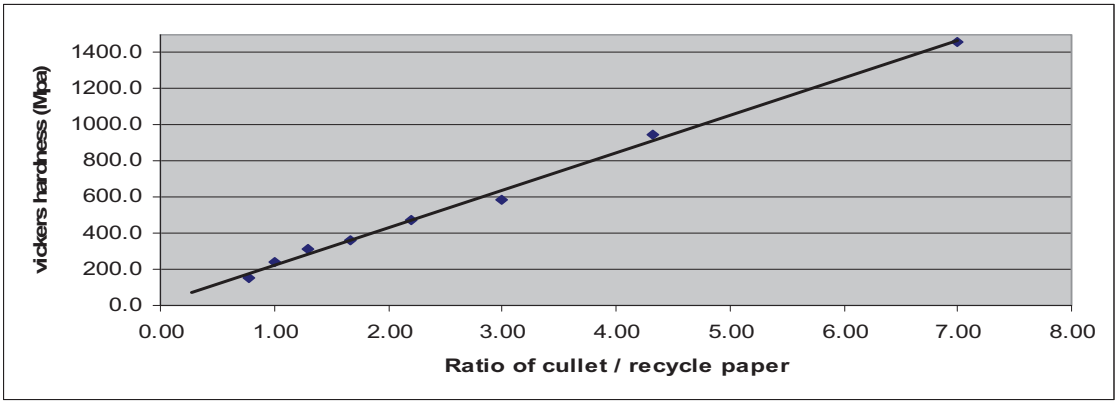


Figure 4. Hardness versus cullet / incinerated paper ratio

Figure 4 shows the plot of hardness against the cullet/incinerated paper ratio. From Figure 4, it can be seen that the hardness increases as the cullet content is increased. This result indicates that the ceramic becomes more compact as the cullet level is increased. This is true since at this stage, the glass phase vitrified in the ceramic matrix [12]. The micrograph at higher cullet level also confirms this result.

4. Conclusion

From the result and discussion, some conclusions can be made. The ceramic-based on the incinerated paper-cullet-kaolin clay has successfully been prepared. The EDAX analysis shows that the ceramic contained largely of SiO_2, Al_2O_3 and CaO. It is found that the major phase occurrence are Quartz (SiO_2), Wollastonite ($CaSiO_3$) and Anorthite ($Ca(Al_2SiO_8)$). It is observed that the microstructural morphology shows that the ceramic with higher cullet level exhibits a smoother surface but the one with lower cullet level shows a granular rough texture. Meanwhile the thermal shrinkage and hardness of this ceramic are found to be compositional dependence.

Acknowledgements

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